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FULL LENGTH ARTICLE

Optimum injection dose rate of hydrogen sulfide scavenger for treatment of petroleum crude oil

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Abstract Hydrogen sulfide H_2S scavengers are chemicals that favorably react with hydrogen sulfide gas to eliminate it and produce environmental friendly products. These products depend on the type and composition of the scavenger and the conditions at which the reaction takes place. The scavenger should be widely available and economical for industry acceptance by having a low unit cost. The optimum values of H_2S scavenger injection dose rate of scavenging hydrogen sulfide from the multiphase fluid produced at different wells conditions in one of the Petroleum Companies in Egypt were studied. The optimum values of H_2S scavenger injection dose rate depend on pipe diameter, pipe length, gas molar mass velocity, inlet H_2S concentration and pressure. The optimization results are obtained for different values of these parameters using the software program Lingo. In general, the optimum values of H_2S scavenger injection dose rate of the scavenging of hydrogen sulfide are increased by increasing of the pipe diameter and increasing the inlet H_2S concentration, and decreased by increasing the pipe length, gas molar mass velocity and pressure.

1. Introduction

Hydrogen sulfide is a colorless gas, with an offensive odor and a sweetish taste. It is soluble in water, alcohol, oils, and many other solvents. It has specific gravity of 1.1895 with reference to air. It is considered a weak acid; it is toxic to humans and corrosive to metals. Hydrogen sulfide can be dangerous to personnel on the surface as it is extremely toxic to human and even animal life, and is extremely corrosive to most metals as it can cause cracking of drill pipe and tubular goods, and destruction of testing tools and wire lines.

The hydrogen sulfide content of fluids in the permeable formations of oil wells has an important impact on the economic value of the produced hydrocarbons and production operations [1,2]. Typically, the sulfur content of crude oils is in the range of 0.3–0.8 wt% and the hydrogen sulfide content of natural gas is in the range of 0.01–0.4 wt%, although concentrations of hydrogen sulfide in natural gas of up to 30 wt% have been reported. Several recent reports have claimed a systematic increase in the sulfur content of crude oils over the past 10–20 years and anticipate further significant increases in the concentration of hydrogen sulfide in both oil and natural gas [3,4]. The correlation between the hydrogen sulfide concentration of produced hydrocarbons from the Norwegian continental shelf and the reservoir temperature; above about 110 °C indicates that the hydrogen sulfide content of produced

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hydrocarbons increases exponentially with temperature, while below this temperature the hydrogen sulfide concentration is negligible [5–7].

The souring of petroleum reservoirs caused mainly by sulfate-reducing bacteria can increase the concentration of hydrogen sulfide in produced fluids to the point of making it necessary to inject expensive chemical scavengers in production pipelines so that the corrosion and operational risks can be minimized [8–10]. In-line scavenging of hydrogen sulfide is the preferred method for production of crude oil containing low hydrogen sulfide levels from subsea wells, especially where the well is tied back via a flowline to a host facility at which there is no provision for H_2S scavenging and/or where H_2S removal facility is too expensive and/or impractical to install [11].

As a result of this method, the hydrogen sulfide content of the crude oil that is delivered to the platform is reduced to safe and commercially acceptable levels and reaction by-product formation is manageable. The formation water provides a carrier phase for some of the reaction products and enhances the dispersion of some insoluble reaction products in the coproduced aqueous phase [12,13]. This study focuses on the estimation of the optimum value of H_2S scavenger injection dose rate according to the available wells' field data obtained from an existing oil well in Petrobel Petroleum Company in Egypt as in Table 1.

2. Objective function and constraints

The following empirical equation (1) is used as the objective function to obtain the optimum H_2S scavenger injection dose rate using the software program Lingo [14–16].

$$R_J = \left[\frac{\ln\frac{y_{in}}{y_{out}} G_V}{C_1 G_V^{C_2} D^{C_4} PZ}\right]^{1/C_3} \quad (1)$$

where

R_J = H_2S scavenger dose injection rate, l/day.
y_{in} = inlet H_2S concentration, ppmv.
y_{out} = outlet H_2S concentration, ppmv.
G_V = gas molar mass velocity, lb mol/(h ft^2).
D = pipe diameter, in.
P = pressure, psig.
Z = pipe length, ft and
C_1, C_2, C_3, C_4 = regression coefficients constant.

Constraints

$100 \leqslant P \leqslant 600$.
$100 \leqslant y_{in} \leqslant 6000$.
$1800 \leqslant G_v \leqslant 33{,}000$.
$10 \leqslant Z \leqslant 1000$.
$2 \leqslant D \leqslant 10$.

3. Results and discussion

The optimum value of H_2S scavenger injection dose rate as in the empirical equation (1) is a function of the factors; pipe length, pipe diameter, gas molar mass velocity, inlet concentration of H_2S and pressure. The optimization results of the effective parameters on the optimum value of H_2S scavenger injection dose rate are studied in the following section.

3.1. Optimum H_2sscavenger injection dose rate at different pipe diameters

Table 2 shows the optimum values of H_2S scavenger injection dose rate at different values of pipe diameters. At pipe diameters equal to 2, 4, 6, 8 and 10 in., the optimum H_2S scavenger injection dose rate is equal to 66.78924, 132.7479, 198.39, 263.8448 and 329.144 liter per day, respectively. At these pipe diameter values the optimum values of pressure, H_2S inlet, pipe lengths ft, H_2S outlet and gas molar mass velocity, (lb mol/(h ft^2)) are 600 psig, 6000 ppmv, 1000 ft, 10 ppmv and 33,000 lb mol/(h ft^2) respectively.

In general, the estimated results show that the effect of pipe diameter had a marked effect, increasing the pipe diameter caused an increase of the optimum value of H_2S scavenger injection dose rate due to reduction of gas velocity and turbulence and hence, absence of good mixing between the scavenger and the crude.

3.2. Optimum value of H_2s scavenger injection dose rate at different pipe lengths

Table 3 shows the optimum values of H_2S scavenger injection dose rate at different pipe lengths (distance from the downstream of the injection point). At pipe lengths equal to 10, 300, 500, 700, 1000 ft the output results of optimum value of H_2S scavenger injection dose rate are equal to 890.3605, 258.7447, 145.6542, 99.75838 and 66.78924 liter per day, respectively, while the optimum values of pressure 600 psig, H_2S inlet 6000 ppmv, pipe diameter 2 in. ft, H_2S outlet 10 ppmv and gas molar mass velocity, lb mol/(h ft^2) 33,000 do not change at these pipe lengths values. Consequently, by increasing the pipe length the optimum value of H_2S scavenger injection dose rate will be decreased due to the increase in retention time of reaction.

Table 1 Well fields' production condition at petrobel Petroleum Company in Egypt for (Wells No. 113–173, 113–188, 113–104, 113–142 and 113–124).

Item	Well No.				
	113–173	113–188	113–104	113–142	113–124
Net Prod. bbl/d	1295	1687	136.35	605	85.2
Pressure, psi	110	150	400	180	120
Temp. °C	40–50	40–50	50–55	50–55	50–55
H_2S blank, ppmv	6000	12,000	1700	1600	200
Pipe diameter, in.	4	4	4	4	2
Retention time, h	2.5	3	3	3	2